

Cosmology with Galaxy Clusters

Peter Schuecker

Universality of Cluster-XLF

Exotic Cosmic Fluid

Brane-world Effects

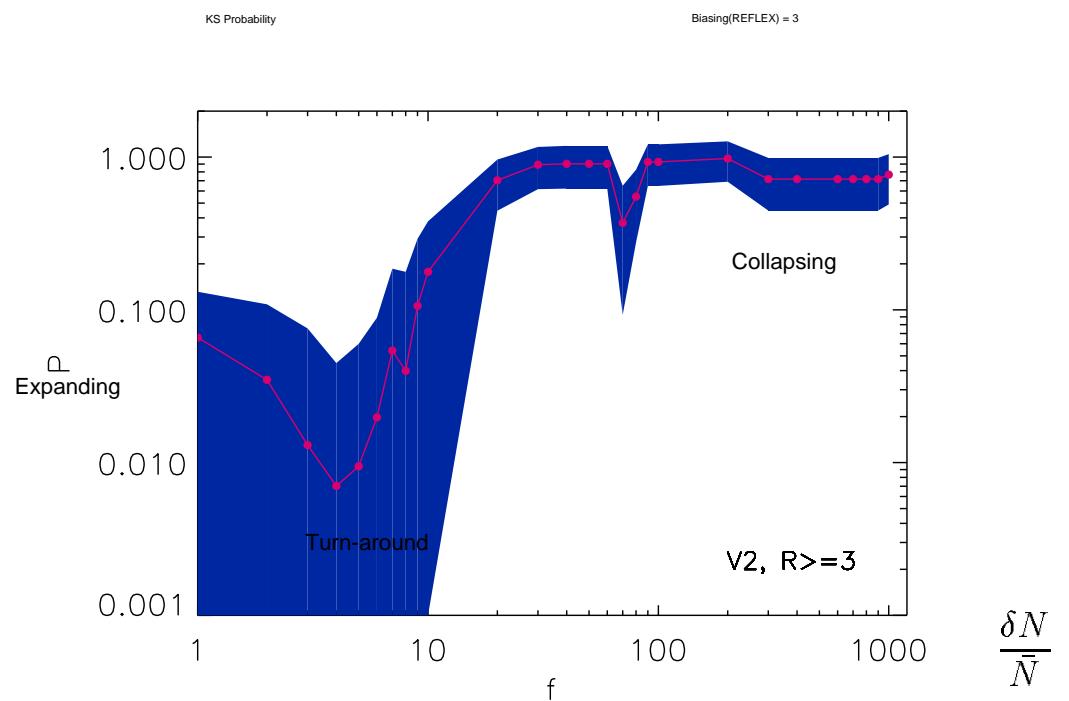
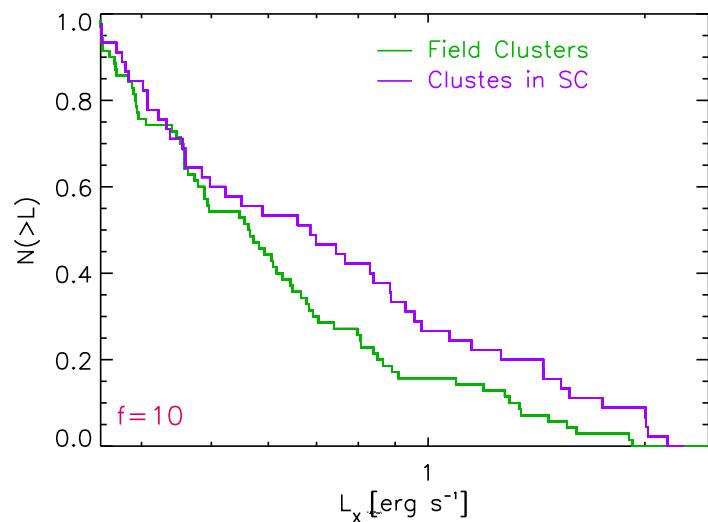
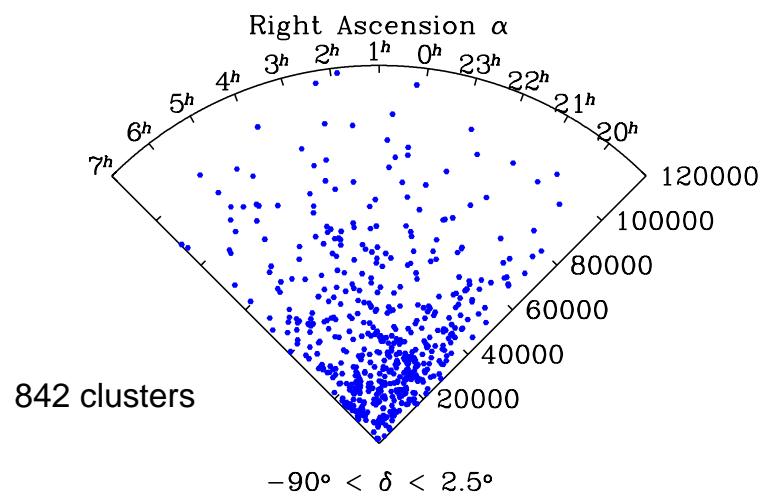
Cluster Finder

H. Boehringer, C.A. Collins, L. Guzzo & REFLEX team

G. Amosov, A.J. Banday, R.R. Caldwell, N. Nowak

C. Raeth, C.S. Rhodes, W. Voges & GAVO, N.N. Weinberg

Universality of the Cluster XLF



Higher fraction of luminous clusters
in super-structures
XLF depends on super-structure environment
 $f=3-10$: super-structures at turn-around

Nowak et al. (2004)

Mass Function: Theory

Excursion set theory (Bond et al. 1991)

+ ellipsoidal collapse

(Sheth & Tormen 2002)

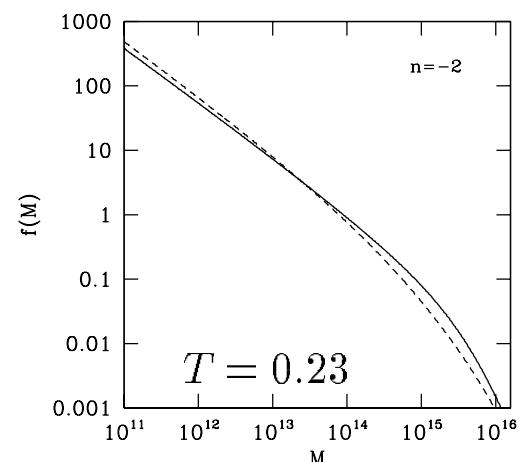
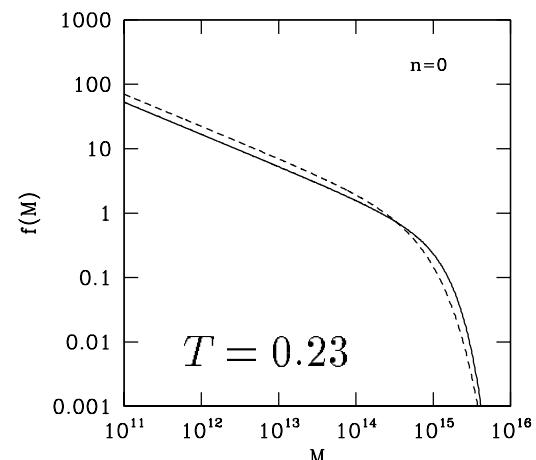
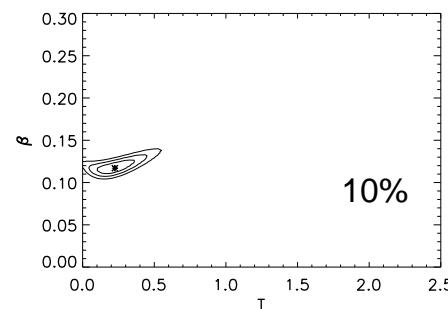
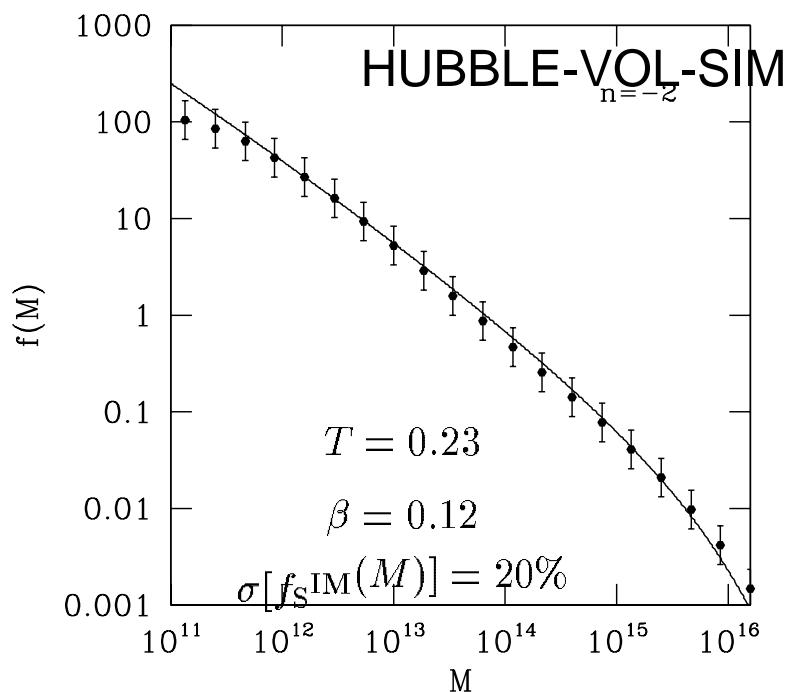
+ correlation with formation history, i.e.

environment (Amosov & Schuecker 2003):

$$\beta = 0 = T$$

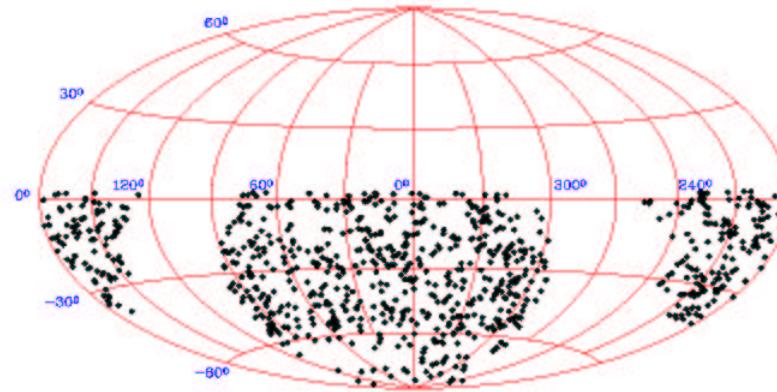
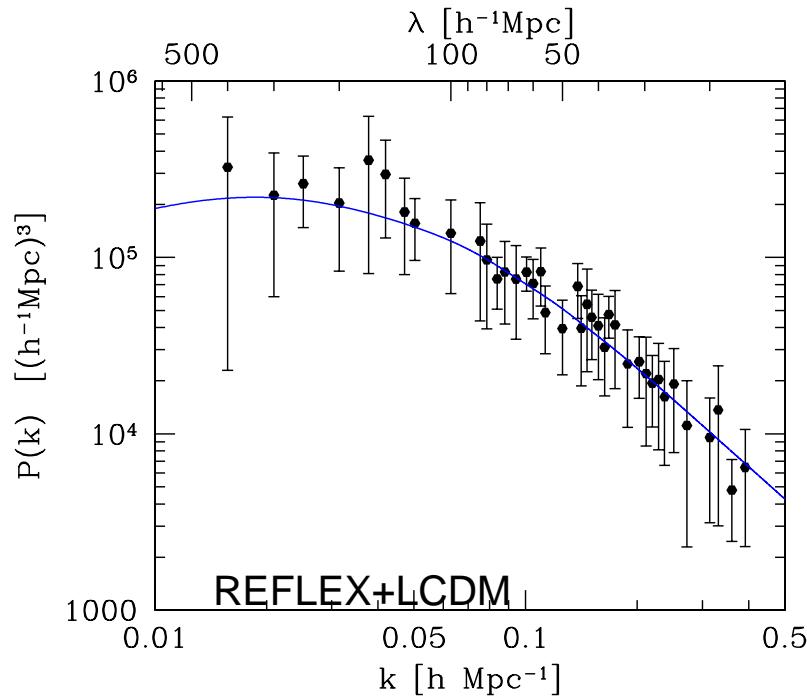
β Parameter

T Parameter



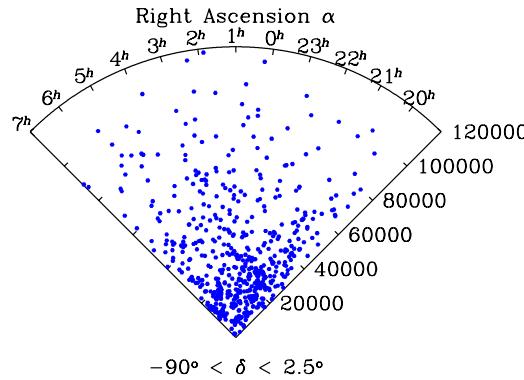
$f(M)$ with <10% errors allow detection of correlation with formation history

Plane Wave Decomposition: Leakage Problem

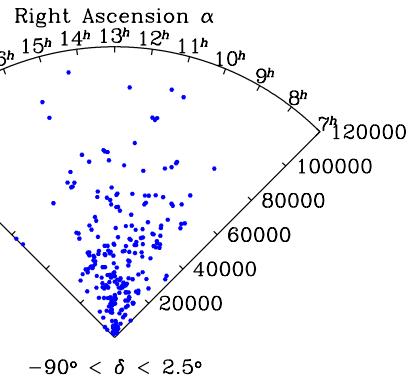


$$\tilde{P}_{\text{obs}}(k) \approx \frac{1}{(2\pi)^3} \int d^3\vec{k}' P(\vec{k}') |W(\vec{k} - \vec{k}')|^2$$

$P(k)$ convolved with
Survey-Window(k)

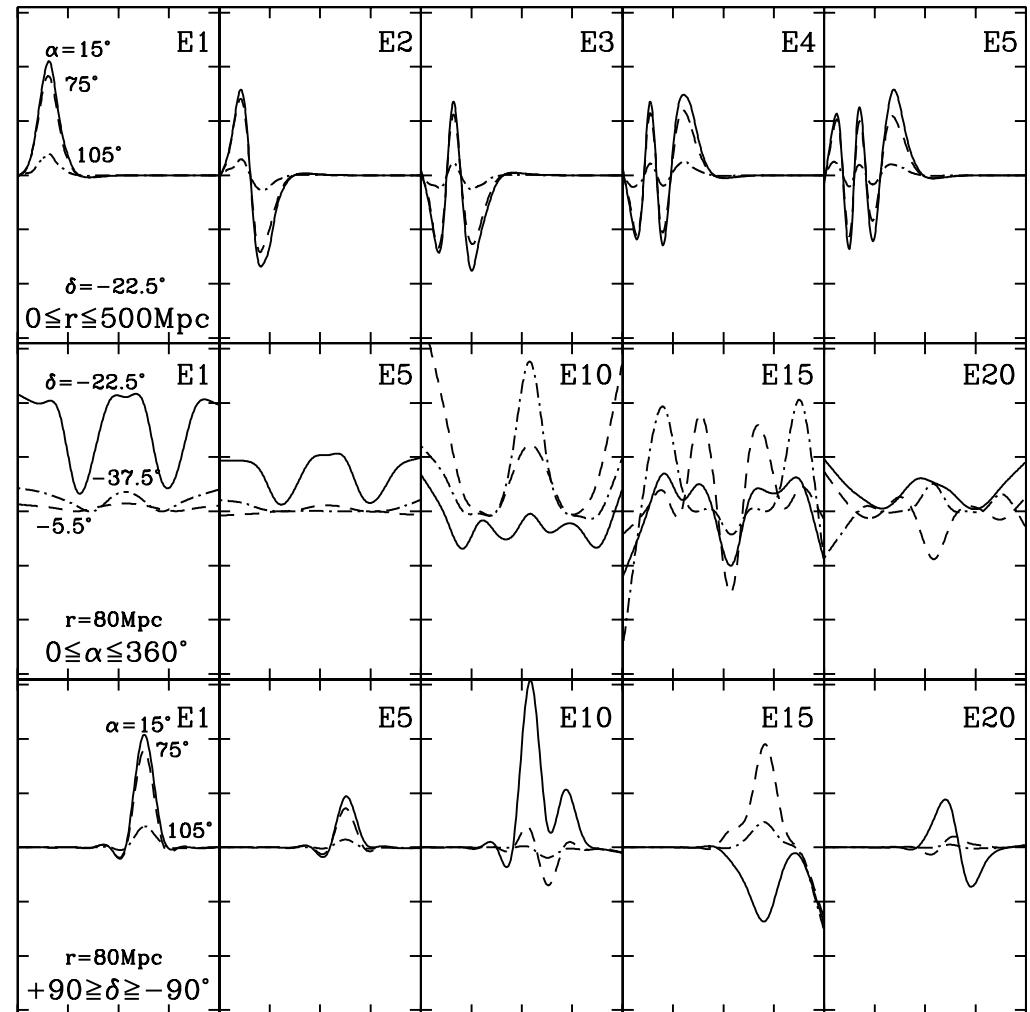
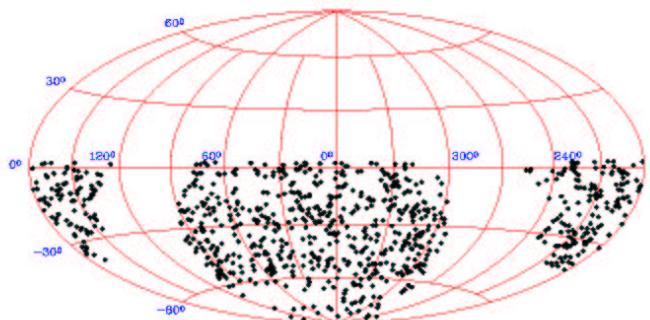


Survey-specific modes needed



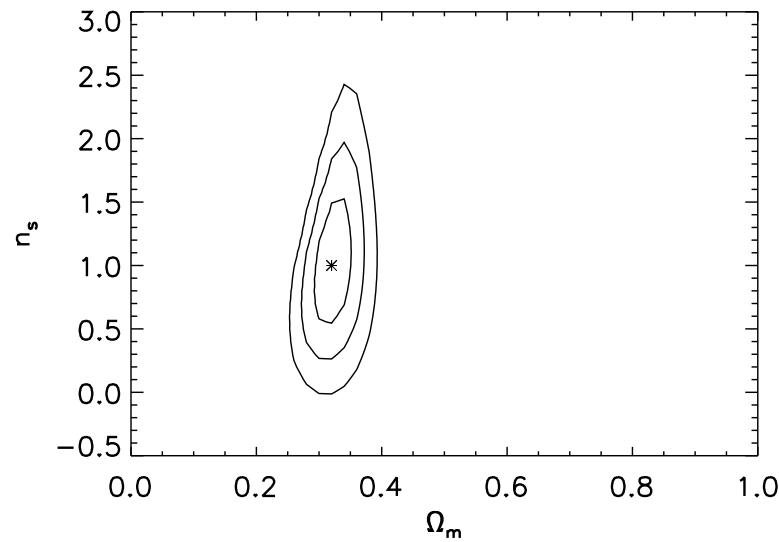
REFLEX Eigenmodes

3D REFLEX eigenvectors
Plots of 1D projections

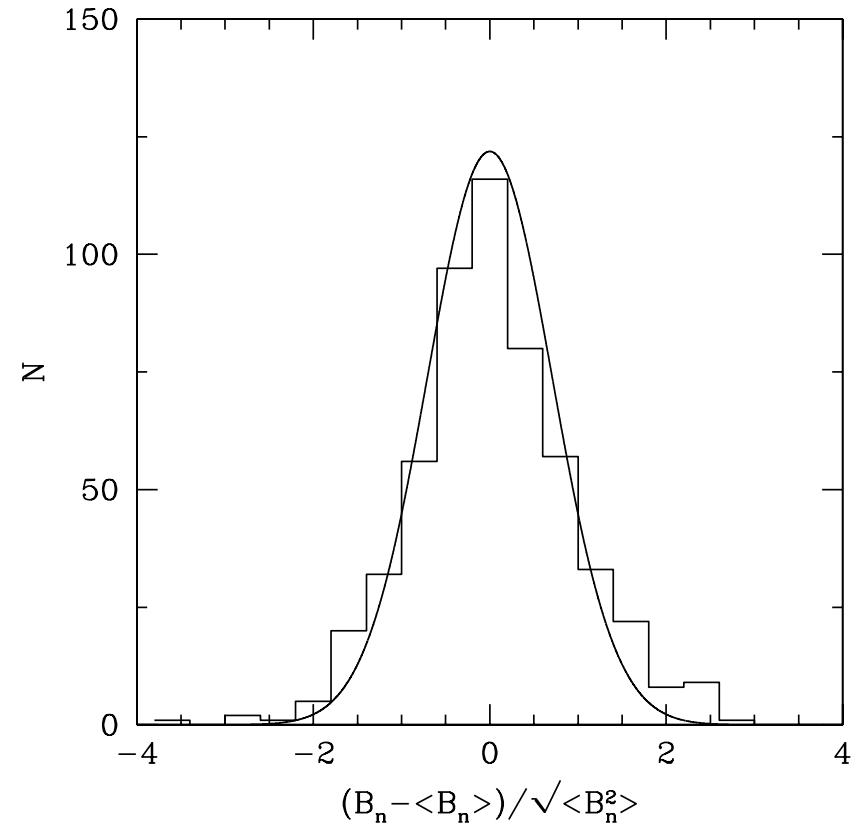


Radial direction (upper panel)
R.A. direction (middle panel)
DEC. direction (lower panel)

Primordial Properties: Gaussianity



REFLEX not really sensitive
to primordial properties



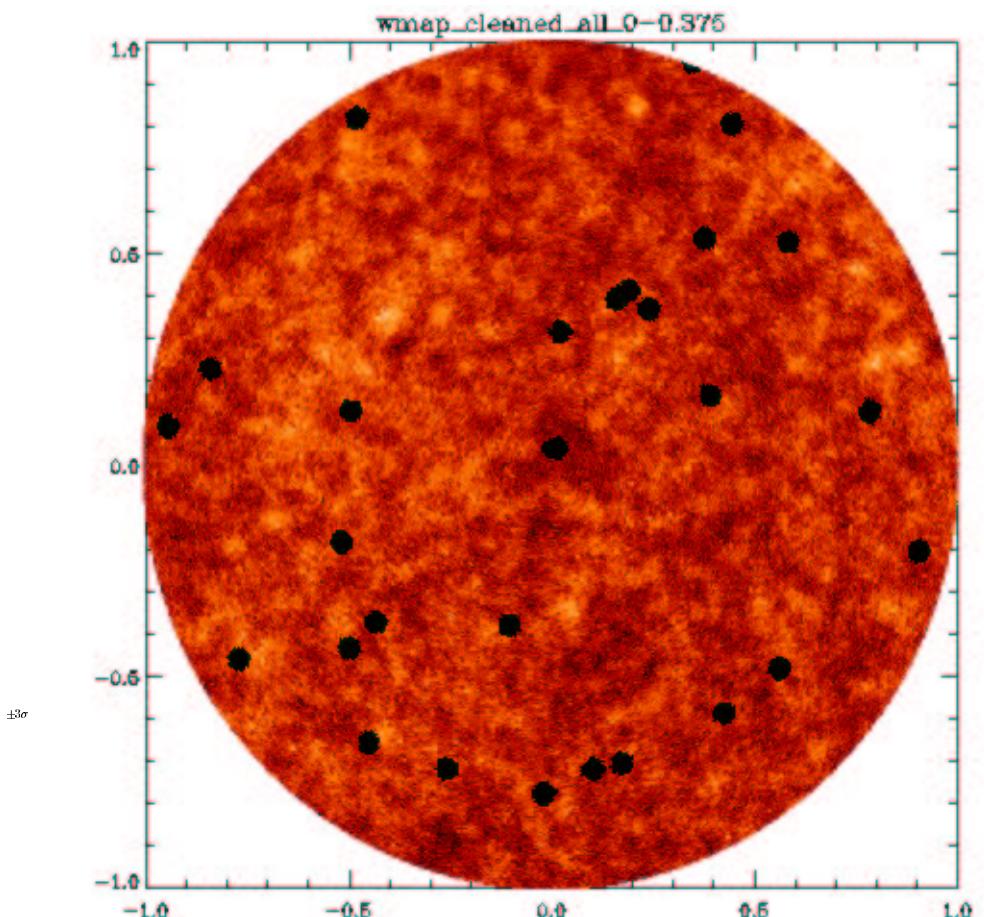
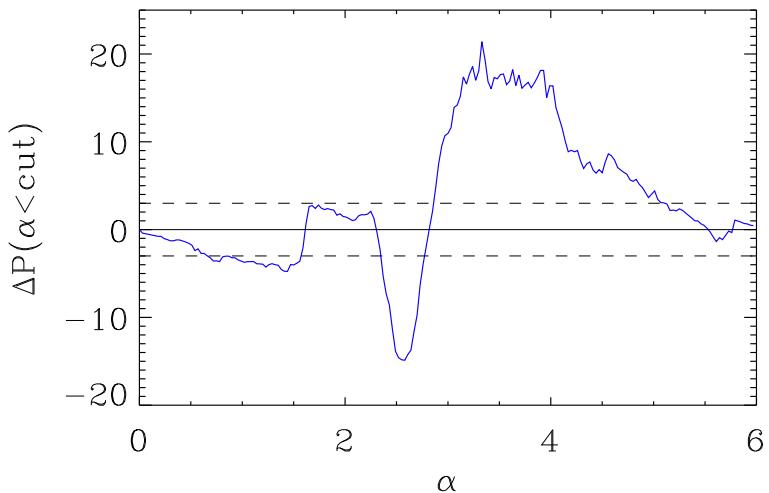
Cosmological tests with REFLEX
Schuecker et al. (2001, 2002, 2003a,b)
in mildly non-linear regime

Gaussianity test on 0.1-1 Gpc
Probability = 0.93

WMAP Gaussian?

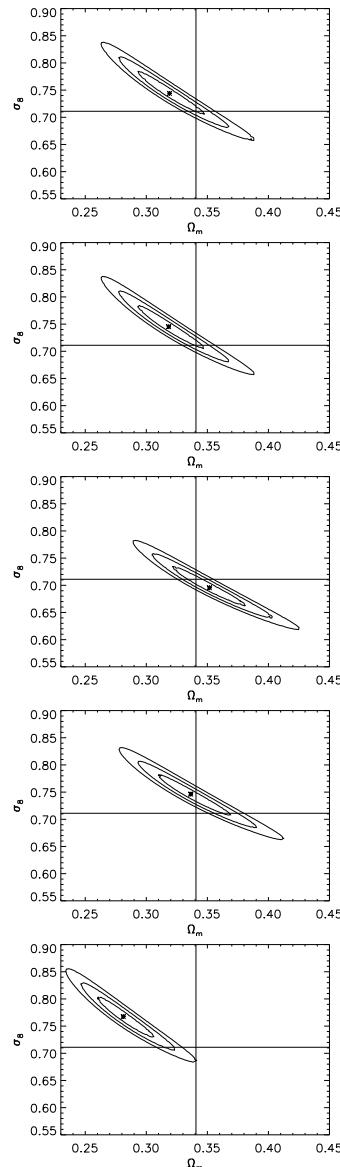
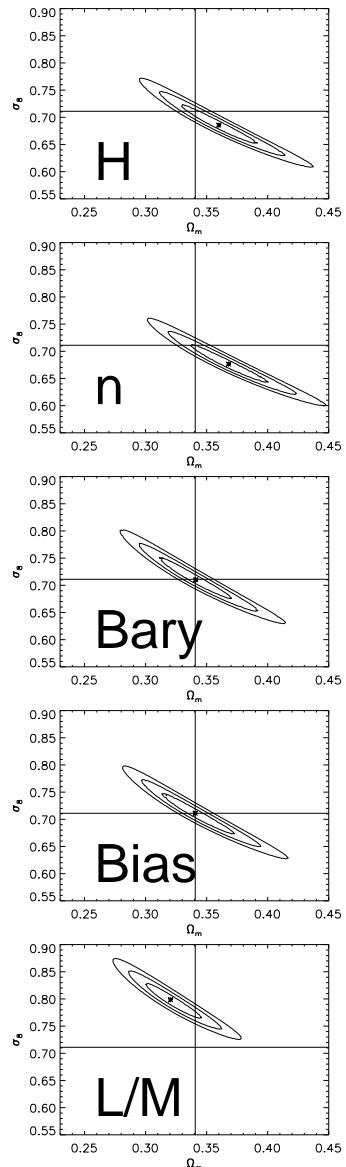
Surrogate Resampling +
Scaling Index
(Raeth & Schuecker 2003)

Non-Gaussianity in WMAP

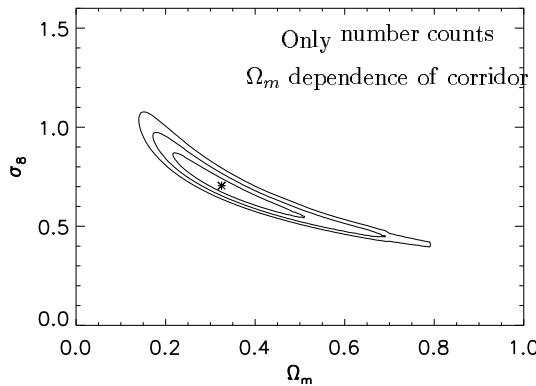


C. Raeth, P. Schuecker, A.J. Banday

Systematic Errors of Cosmological Tests



$0.28 \leq \Omega_m \leq 0.37 \quad 0.56 \leq \sigma_8 \leq 0.80$
From Number counts + fluctuations



H: Hubble constant
n: spectral index (HZ)
Bary: baryon density
Bias: cluster biasing model
L/M: luminosity-mass relation

Schuecker et al. (2003a)

Exotic Cosmic Fluid?

Nul – Energy – Condition

$$G_{\mu\nu} k^\mu k^\nu \geq 0$$

$G_{\mu\nu}$ Einstein tensor

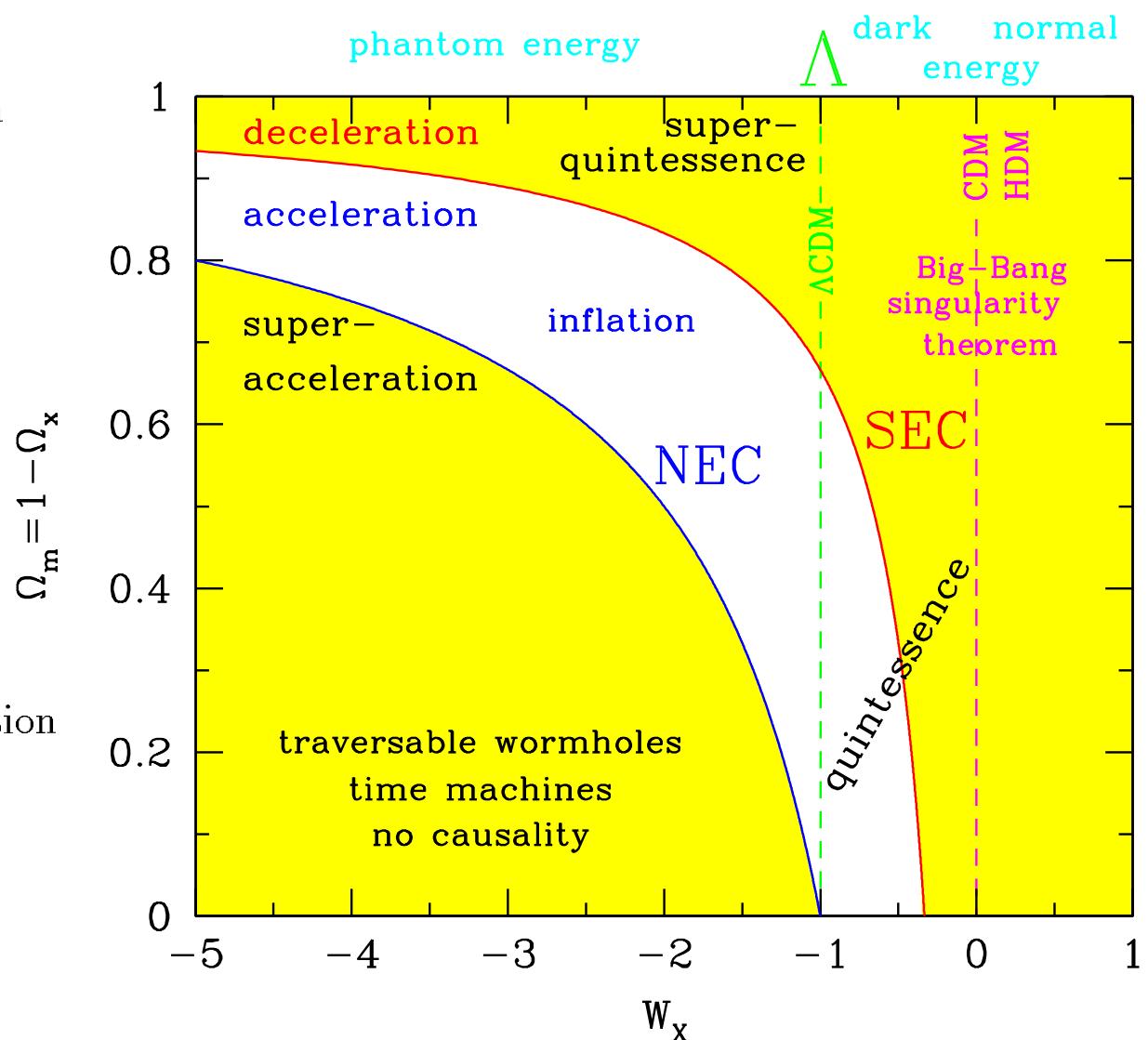
k^μ nul vector

Strong – Energy – Condition

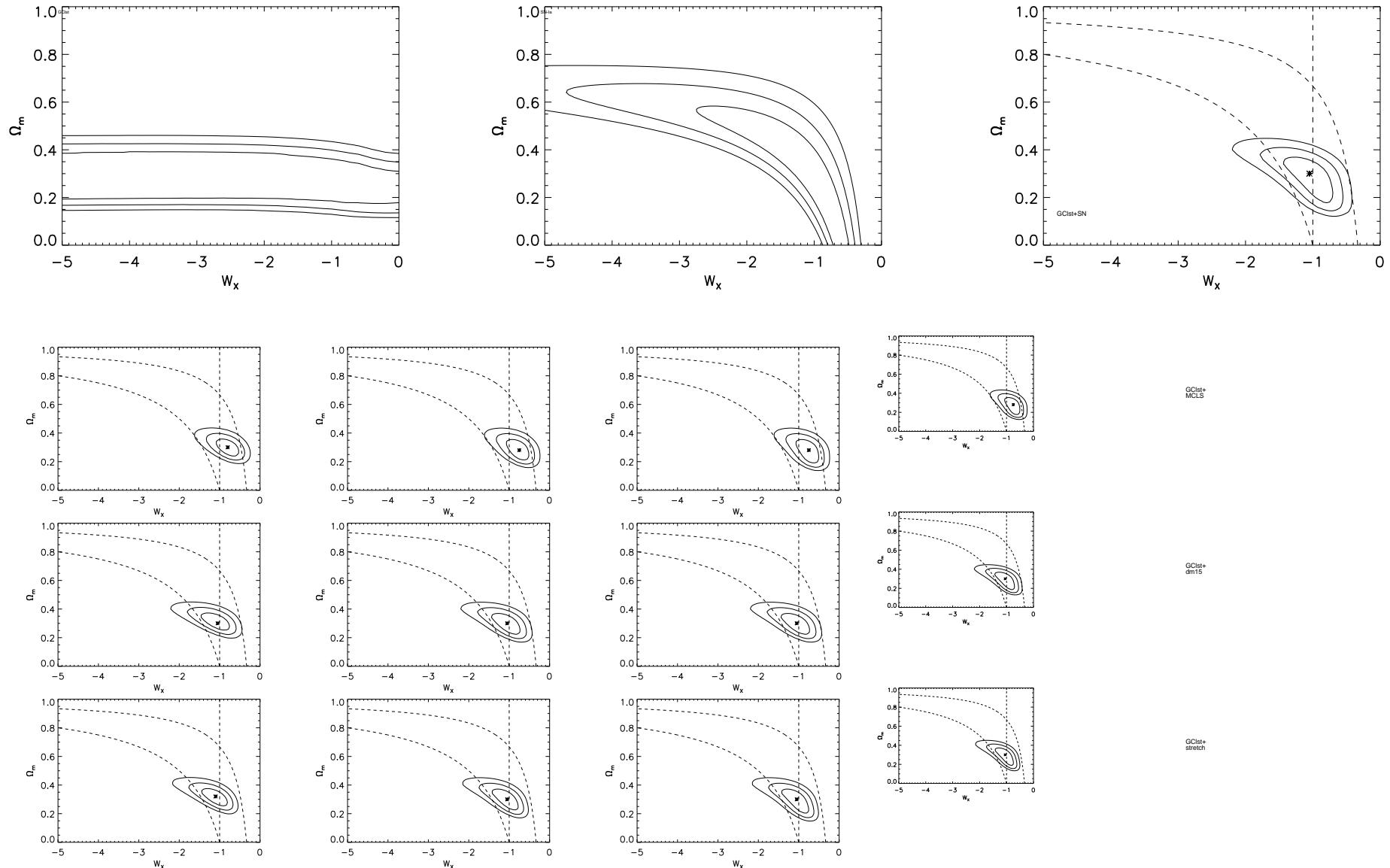
$$R_{\mu\nu} v^\mu v^\nu \geq 0$$

$R_{\mu\nu}$ Ricci tensor

v^μ time – like



Exotic Cosmic Fluid?



Energy/Matter vs Gravity Sector

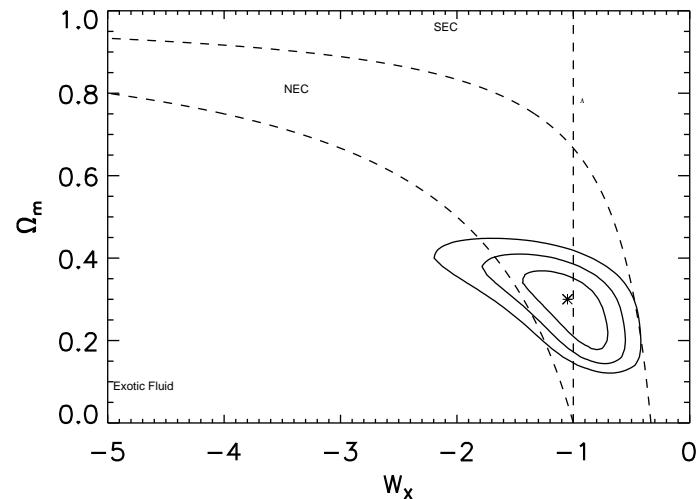
GClst+SNla (Schuecker et al. 2003b):
NEC fulfilled, SEC violated

Not much room left for
an exotic cosmic fluid!

What explains observations?

Classical gravity breaks down at high enough
energies

M-theory ideas (which also need NEC) are implemented in
brane-worlds



Brane-World Gravity

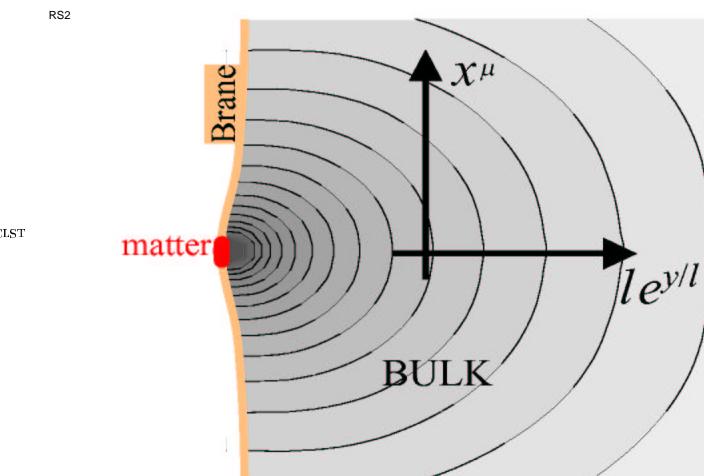
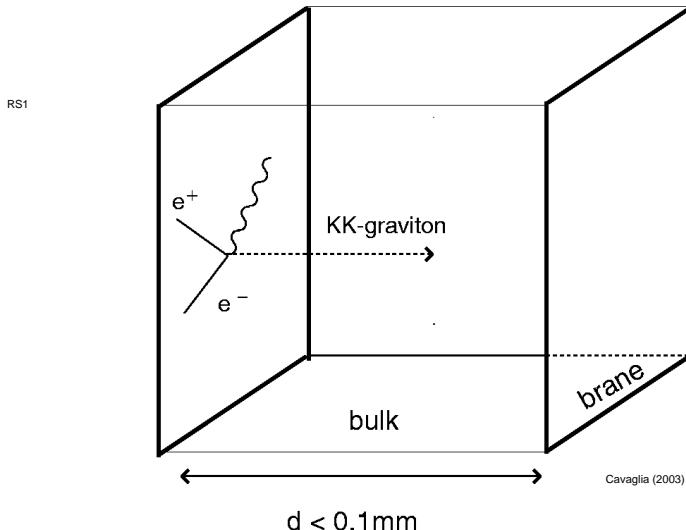
Universe located on a
3+1 dimensional brane

Brane exchanges only GRAVITATIONAL
energy/momentum with bulk (string idea)

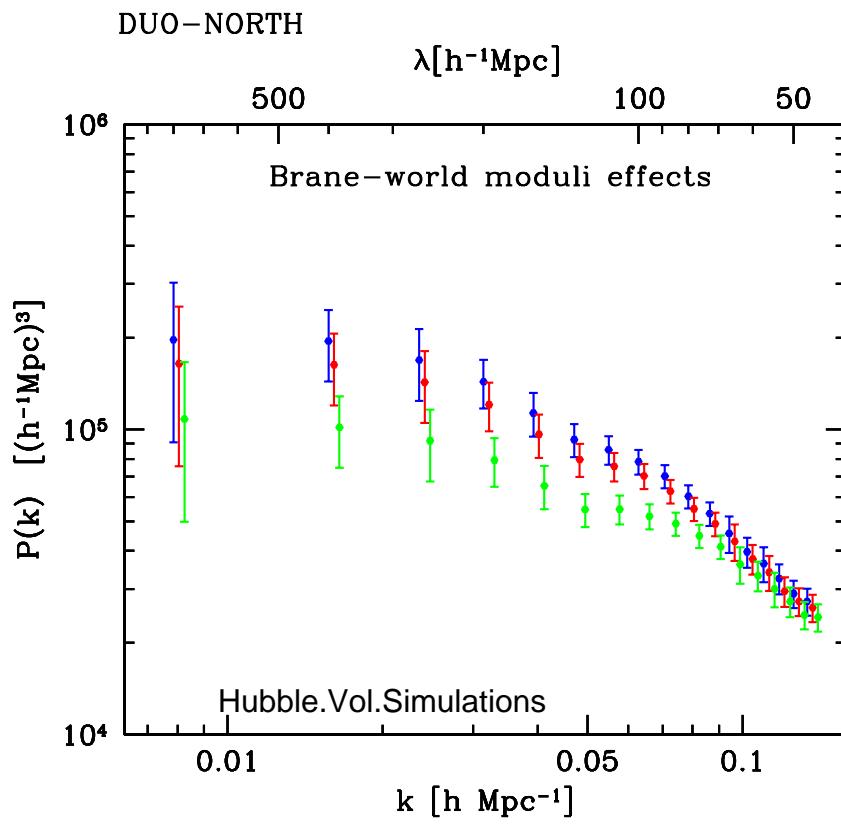
Gravitational effects between brane
and bulk can explain observations

Brane and bulk are perturbed

Perturbed brane-world at low
energies = biscalar tensor theory
(Rhodes et al. 2003)

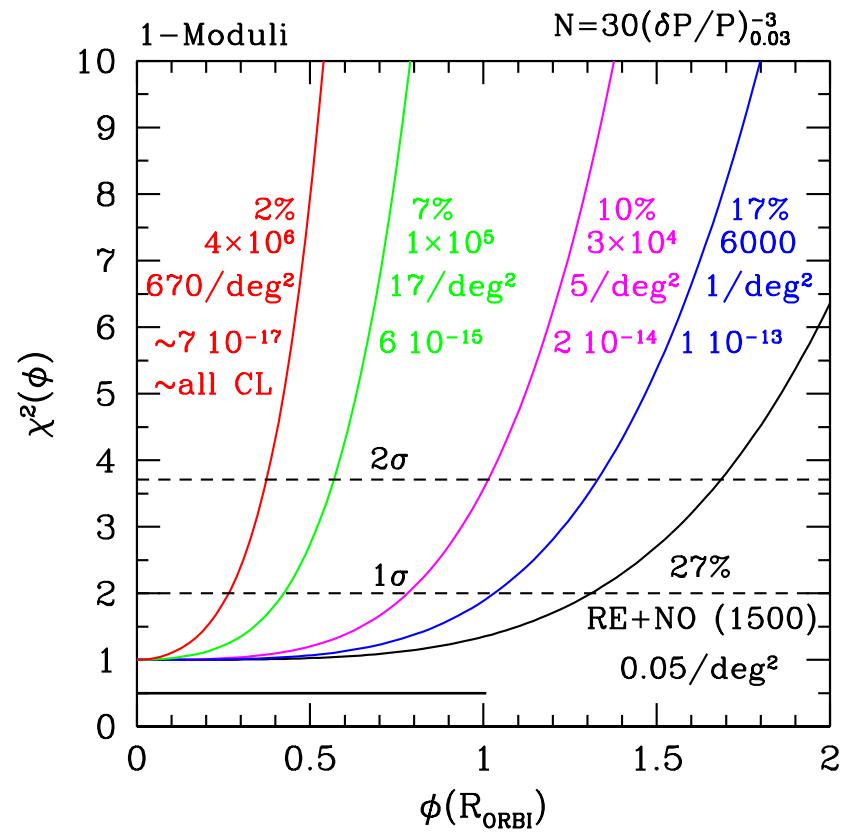


DUO-NORTH: $P(k, z=0)$ on large scales



5-10% effects on 0.1-1 Gpc/h scales
Structure growth similar to LCDM

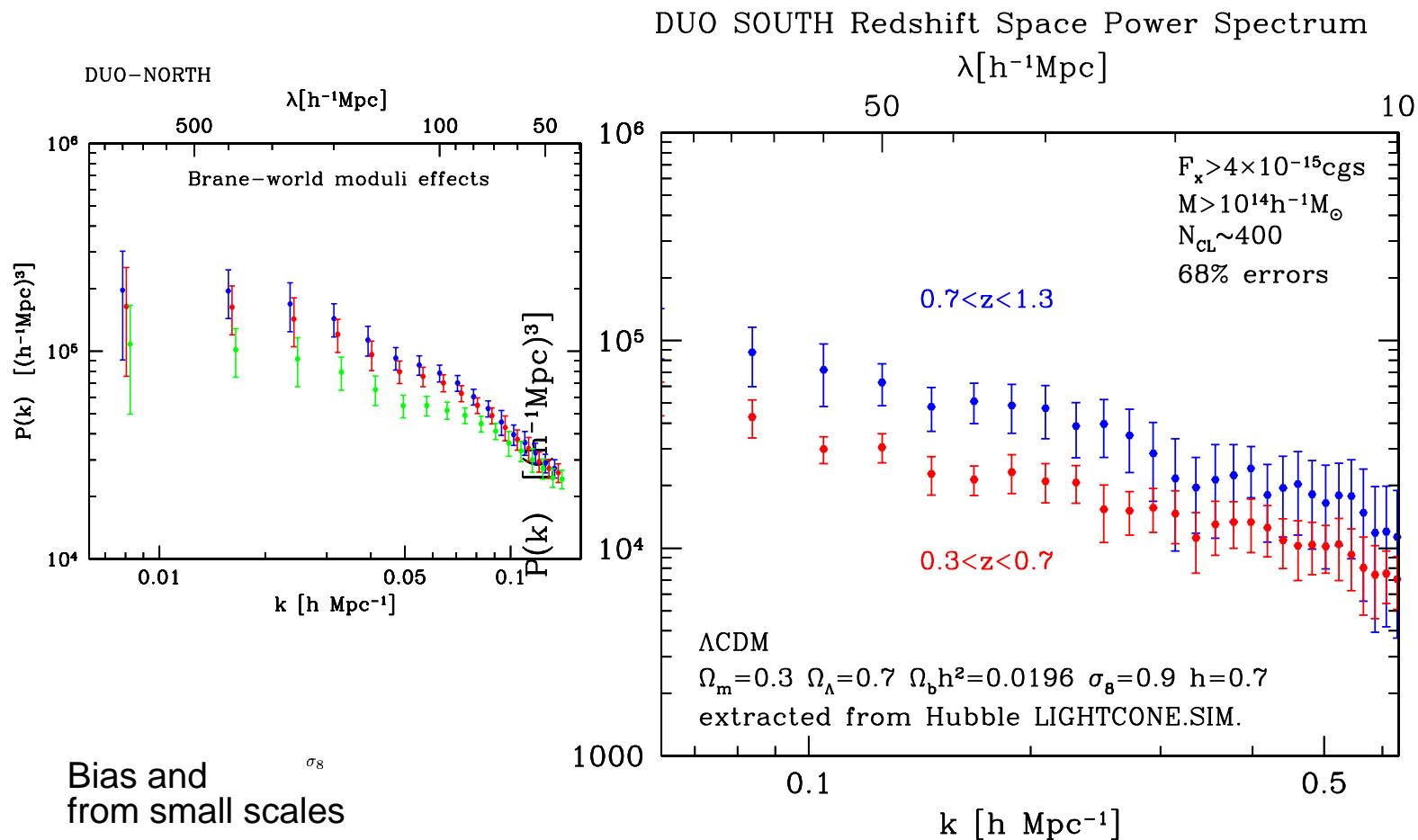
Brane-LCDM flatter than FLRW-LCDM



Interesting sample: >30,000 clusters

Schuecker et al., in prep.

DUO-South: $P(k, z)$ on small scales



Brane Viewpoint of w

$$w_{\text{tot}} = \frac{w + (1+2w)\frac{\rho}{\lambda} + \frac{\rho^*}{3\rho}}{1 + \frac{\rho}{2\lambda} + \frac{\rho^*}{\rho}}$$

ρ energy density on brane
 $\lambda = \frac{3m_p^2}{4\pi l^2}$ brane self gravity (tension)
 ρ^* K energy density in
 spin - 0 mode (dark radiation)

$$l \quad \text{in} \quad V(r) \approx \frac{GM}{r} \left(1 + \frac{2l^2}{3r^2} \right)$$

effective size of extra dimension
 probably 5D graviton $r \gg l$

$$\frac{\rho^*}{\rho_r} \leq 10^{-1} \quad (\text{BBN} + \text{CMB})$$

$$\frac{\rho_r}{\rho_m} \leq 10^{-3}$$

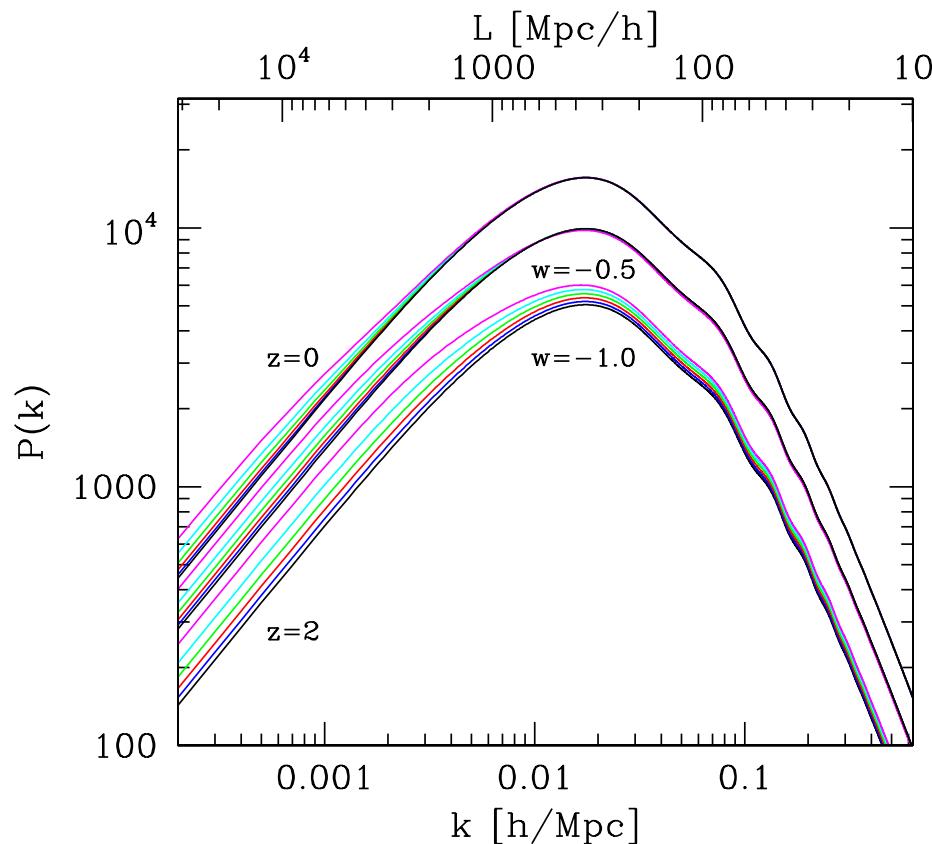
$$\lambda > \text{TeV}^4 \quad (l < 0.2 \text{ mm}, \text{Table - Top})$$

$$\rho_m = 4 \cdot 10^{-59} \Omega_m (\text{TeV})^4$$

$-0.8 \leq w_{\text{tot}} \leq -0.79989$	for $w = -0.8$
$-1.0 \leq w_{\text{tot}} \leq -0.99987$	for $w = -1.0$
$-1.2 \leq w_{\text{tot}} \leq -1.19985$	for $w = -1.2$

Extra-dimension has no
effect on observable w

$P(k,z)$ for Quintessence



No significant clustering of Q-field even on very large scales

Slower growth with less negative w because Q-field dominates increasingly earlier and thus ceases gravitational collapse earlier

FLRW-QCDM same as FLRW-LCDM, but evolution different
Brane-LCDM flatter than FLRW-LCDM

Cluster Finder: Likelihood Filter

$$\ln L_V = - \int_V \lambda(x) dx + \sum_{i=1}^N \ln \lambda(x_i)$$

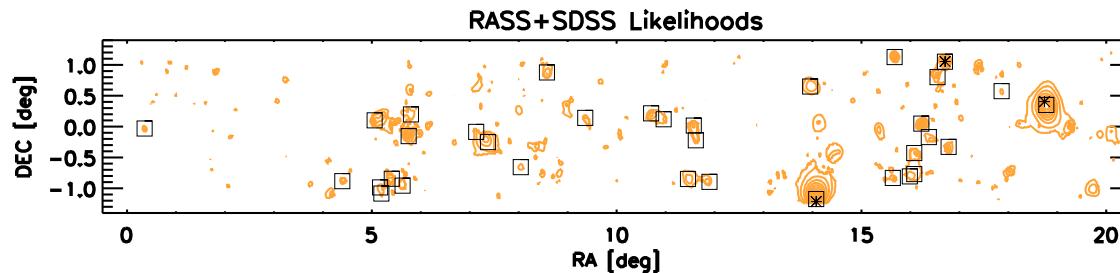
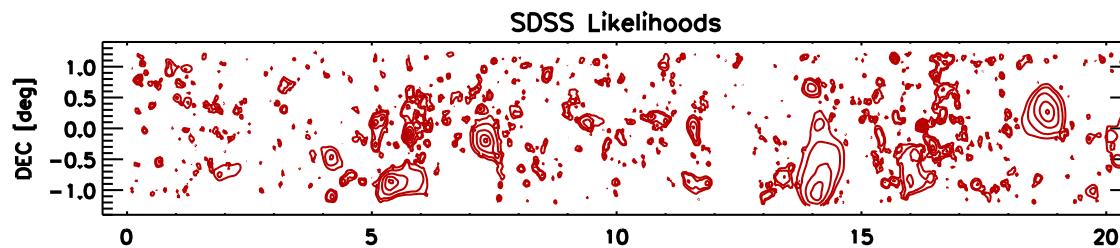
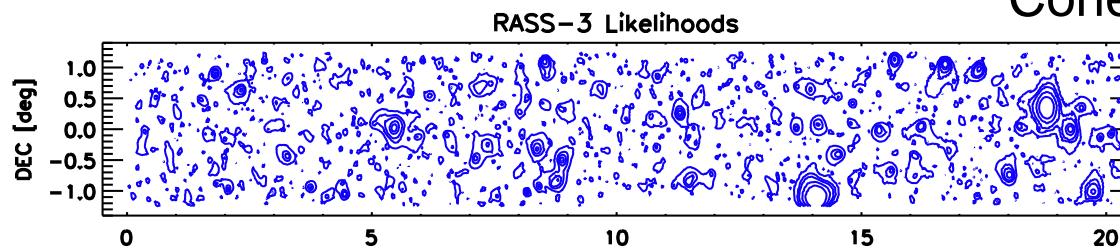
$$\lambda(x) = \bar{\lambda} + \tilde{P}(x)$$

Schuecker et al. (1998, 2003c)

N points (X-ray photons, galaxies
...)

Cone Search within GAVO

RASS photons

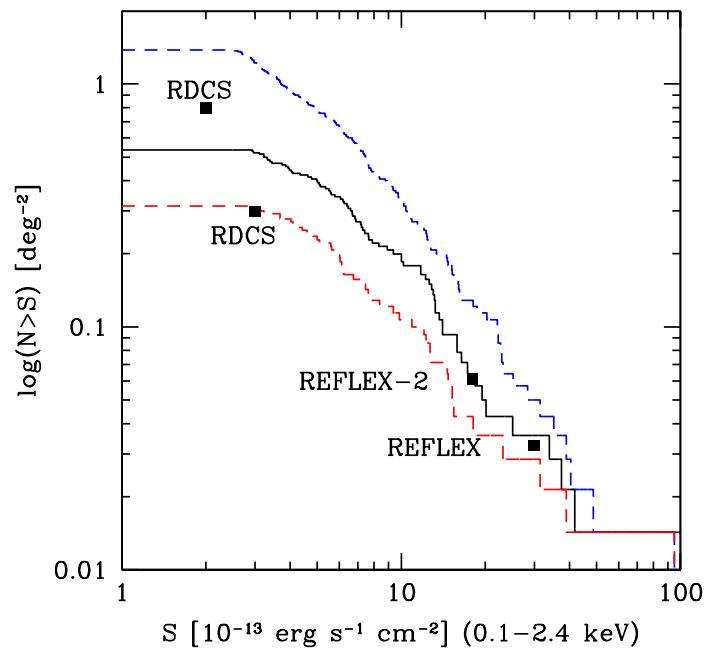


SDSS galaxies

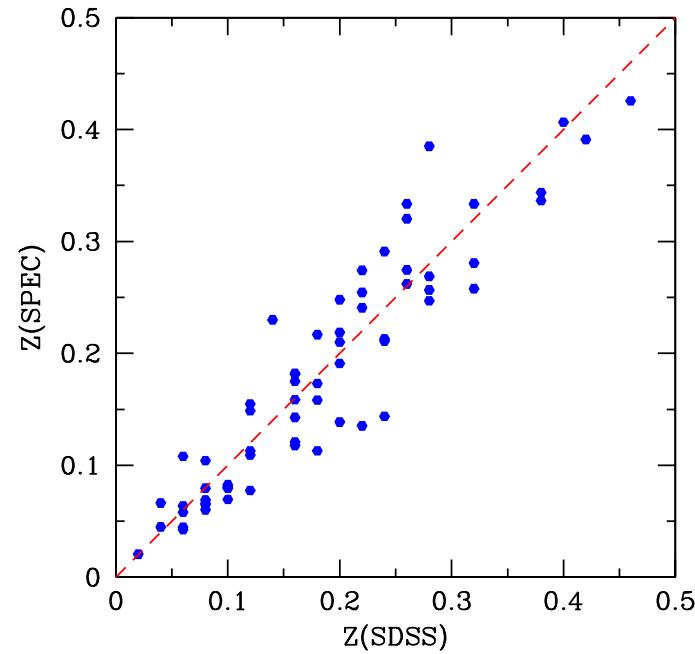
RASS+SDSS

Very Large Cluster Samples

Cluster counts



z estimates



STATISTICAL sample 10x deeper as REFLEX

Future: DUO-North + SDSS or ROSITA + All-Sky
SDSS

Conclusions: Large cluster samples test

- 1) Universality of GClst XLF - details of formation history.
- 2) Gaussianity with GClst (WMAP non-trivial).
- 3) Energy Conditions - Holographic ideas
- 4) Gravity sector with $P(k)$ on large scales.
- 5) Large samples from multiwavelength analyses